THE STUDY OF JOINING STRENGTH BASED ON DIFFERENTIAL JOINING TECHNIQUE

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ABSTRACT

In this thesis, the objective is to study the joining strength based on different joining technique. The focus objective joining strength in this thesis is the spot welding and the adhesive bonding. This technique need to study the effectiveness of the spot welding and adhesive bonding used to join the car body parts and strength of this method need to be analyses. The method used in this thesis are used the five different material with combination with specimen A and A, B and B. The joining used are spot weld and adhesive been applied with the different thickness in 0.65 mm, 0.7 mm and 1.0 mm. the type specimen used are SPCUD 35, SPC 440, PR SPCD, SPCD 440, and INR SPCD. To study the strength of these method, tensile test have been conducted. The experiment been conducted by load vs displacement and strength vs material. The experiment findings showed those spot weld and adhesive bonding with same material shows different strength and also different effect to the parent material. Spot weld bonding will affect the microstructure of specimen and been harden the bonding of joining spot weld. When the force applied higher than strength of the joining, the resistance area around nugget of spot weld start to crack and failure happen at around the nugget itself not at nugget welding. The strength of the spot weld is depending on the strength of material and thickness of material applied to the joining. The strength of adhesive bonding is depending on type of adhesive and surface roughness of the material itself. The shear test shows the adhesive bonding have an average 5.43 MPa and spot weld joining is 6.79 MPa not much different Based on experimental result, adhesive bonding is applicable for automotive body joining.

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ABSTRAK

Tujuan tesis ini adalah untuk mengkaji kekuatan penyambungan berdasarkan perbezaan teknik penyambungan yang digunakan. Tujuannya adalah menfokuskan kekuatan penyambungan dan penyambunganya adalah kimpalan spot dan ikatan adhesive. Teknik ini memerlukan kajian terhadap keberkesanan kimpalan spot dan ikatan adhesive terhadap penyambungan yang digunakan dalam pembuatan komponen badan kereta dan kekuatan teknik ini harus dikaji. Method yang digunakan dalam tesis ini adalah dengan mengunakan lima material berbeza dengan campuran specimen A dan A, B dan B. Penyambungan kimpalan spot dan ikatan adhesive dilakukan dengan perbezaan berketebalan 0.65 mm, 0.7 mm dan 1.0 mm. Jenis- jenis spesimen yang digunakan adalah SPCUD 35, SPC 440, PR SPCD, SPCD 440, dan INR SPCD. Untuk mengkaji kekuatan penyambungan ini, eksperimen tensile test telah dijalankan. Eksperimen dijalankan mengikut daya melawan pemanjangan dan kekuatn penyambungan melawan jenis material. Keputusan eksperimen menunjukkan kimpalan spot dan ikatan adhesive dengan material yang sama menunjukkan perbezaan kekuatan penyambungan dan juga kesan yang berbeza terhadap material yang asal. Keputusan kimpalan spot menunjukkan kesan terhadap mikrostruktur specimen and telah menjadi lebih keras terhadap ikatan penyambungan kimpalan spot. Apabila daya yang dikenakan melebihi kekuatan penyambungan, kawasan yang bertindak melawan daya sekitar diameter kimpalan spot mula menjadi retak dan kegagalan berlaku sekitar pada diameter itu sendiri dan tidak kepada nugget kimpalan. Kekuatan penyambungan kimpalan spot bergantung kepada kekuatan material dan ketebalan material yang dikenakan semasa proses penyambungan dilaksanakan. Manakala ikatan adhesive bergantung kepada jenis-jenis adhesive dan kekasaran permukaan material itu sendiri. Ujian ricih menunjukkan ikatan adhesive boleh bertahan dalam sekitar 5.43 MPa dan kimpalan spot adalah sekitar 6.79 MPa tidak banyak perbezaannya dari segi nilai purata. Berdasarkan keputusan eksperimen, ikatan adhesive boleh dilaksakan dalam penyambungan pembuatan automotif.

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LIST OF SYMBOLS

P	-	Pressure
F	-	Force
A	-	Area
σ	-	Stress
τ	-	Shear Strength
H	-	Heat
I	-	Current
R	-	Resistance
T	-	Thickness
K	-	Heat Losses

LIST OF ABBREVIATION

TGI	-	Tail Gate Inner
TGO	-	Tail Gate Outer
PRR	-	Panel RR Floor
PR	-	Panel Roof
SC	-	Seat Cushion
OTR	-	Outer
INR	-	Inner

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

In automotive industry, different joining techniques is being used in manufacture the body parts of the car like adhesive bonding, spot welding, laser and others. Between the different joining techniques used, the joining strength method between the spot welding and adhesive bonding will be studied to be better method.

1.2 BACKGROUND

Adhesive bonding is used for various applications in the modern automotive industry, ranging from flexible car body sealing to high-performance structural adhesives. Adhesive types with specific properties are available for miscellaneous processing. The requirements for adhesive bonds have increased due to the extended life of the car. In adhesive processing, industrial health and environmental protection aspects have become more and more important. Therefore, it is more difficult but nevertheless necessary to determine requirements for the adhesives to be used in the future. In addition, the demand for quality standards requiring better quality management is increasing. By using welding there is often problem about joint different kinds of materials which effect outer surface quality of welded parts. Complex shape or space which is hard to weld can take advantage of adhesive bonding.

1.3 PROBLEM STATEMENT

In car manufacturing industry, spot welding is majorly used as a joining process to join car body parts. In order to improve the joining method, adhesive bonding and a spot weld need to be comparing to study the strength of the joining.

1.4 OBJECTIVE

The objective of the research is:

i. To compare the effectiveness of adhesive bonding and spot weld used to join the car body parts
ii. To study the strength of these methods.

1.5 SCOPES

The application of adhesive for the joining of parts of different material grades and thickness is commonly used in low volume automotive manufacturing. This study will investigate the strength comparison of the adhesive bonding and spot welding by using the same material specifications. To study the strength of the method used, the shear test be used in the experiment.

1.6 PROJECT FLOW CHART

The Figure 1.1 below is the flow project that has been done in 2 semesters to finish the project research about adhesive and spot weld joining.

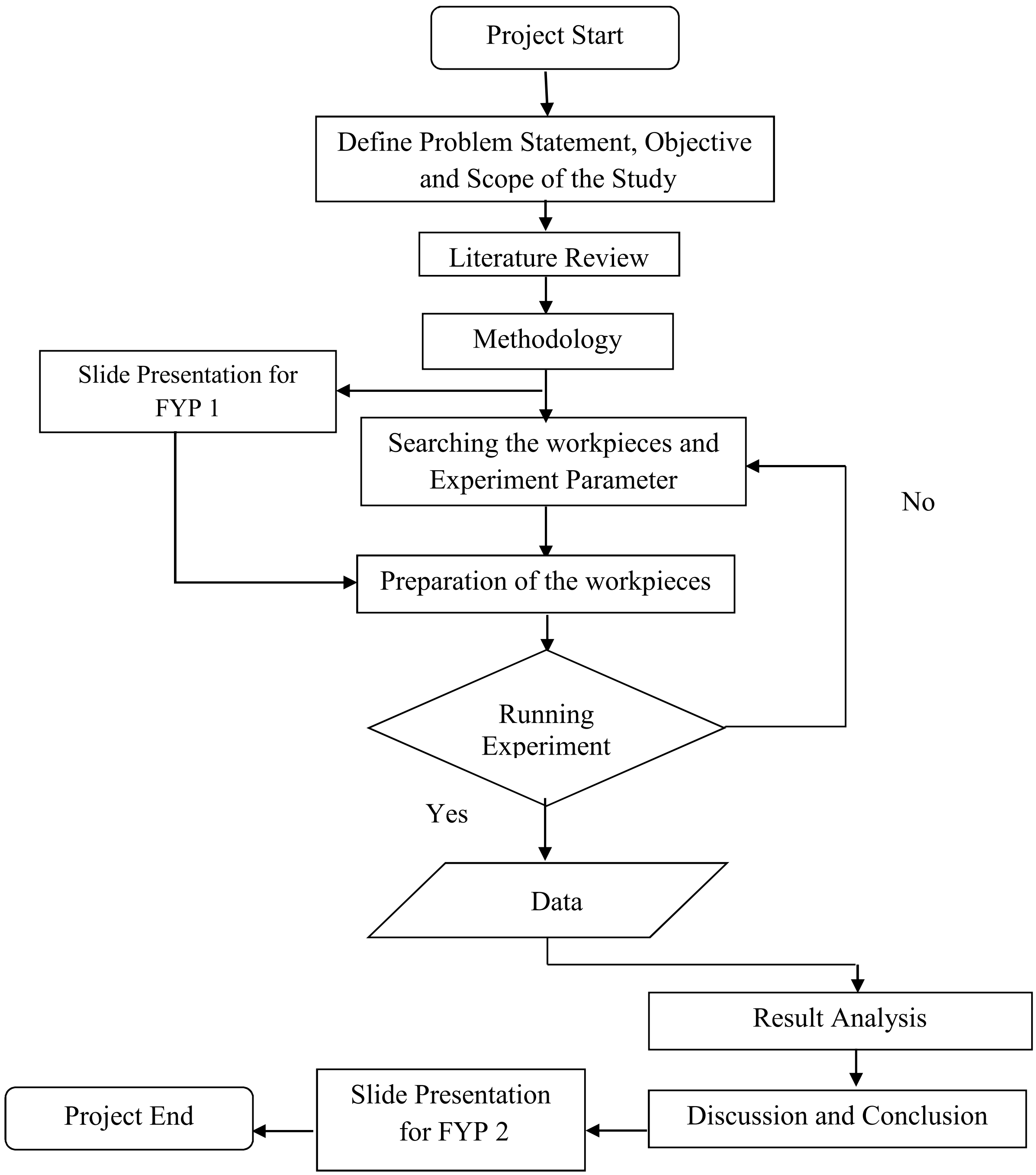


Figure 1.1: Flow chart of the project

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter provides an overview of current research of the adhesive bonding and spot welding included theoretical, experiment result, application and others. Some of the information in this chapter can give extra information which can be useful while doing this project.The pictures below are Figure 2.1 is joining methods currently used in body assembly process in manufacturing industry (Larsoon J. K., 2012).

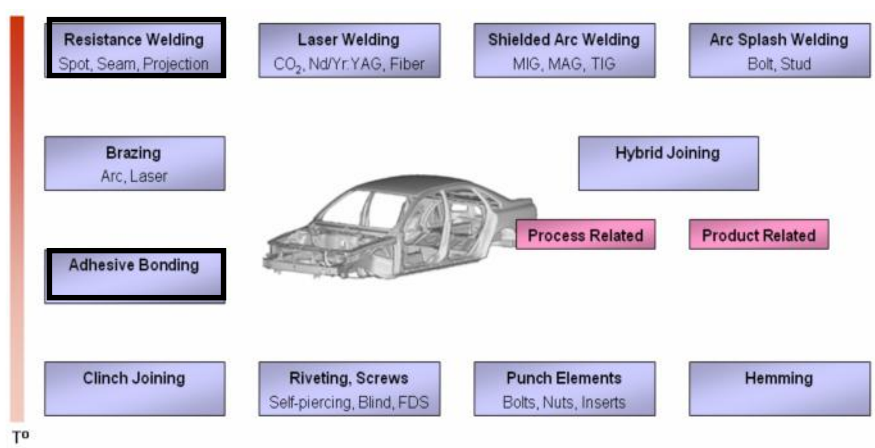


Figure 2.1: Joining methods currently used in body assembly process

Source: High Quality Welding Of Weight Optimized Passenger Car Bodies by Larsson J. K., 2012

2.2 SPOT WELD

Resistance welding is happen when current is caused to flow through electrode tips and the separate pieces of metal to be joined together. The resistance of the base metal to electrical current flow causes localized heating in the joint, and the weld is made. The resistance spot weld is unique because the actual weld nugget is formed internally in relation to the surface of the base metal. The nugget is shape formed from the welding. The picture below is Figure 2.2 shows a resistance spot weld nugget compared to a gas tungsten-arc spot weld (Miller, 2012).

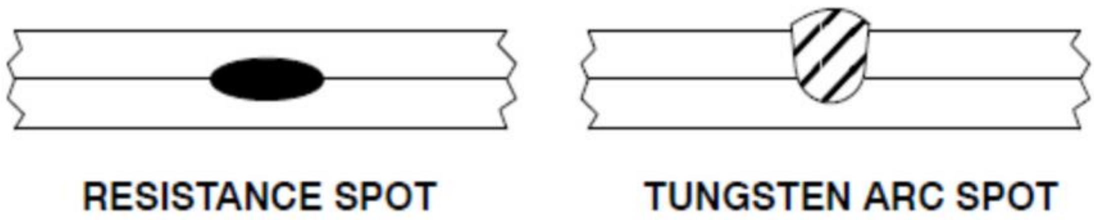


Figure 2.2: Resistance and tungsten inert gas spot weld comparison

Source: Article Handbook for Resistance Spot Welding by Miller, 2012

Resistance spot welding is one of the oldest of the electric welding processes in use by industry today, especially in the automotive industry. The weld is made by a combination of heat, pressure, and time. As the name resistance welding implies, it is the resistance of the material to be welded to current flow that causes a localized heating in the part. The pressure exerted by the tongs and electrode tips, through which the current flows, holds the parts to be welded in intimate contact before, during, and after the welding current time cycle. The required amount of time current flows in the joint is determined by material thickness and type, the amount of current flowing, and the cross-sectional area of the welding tip contact surfaces (Cho Y., 2003).

During the welding process, the amount of electric current is flow from the electrodes to the work pieces. The shape and size of the form weld are controlled by the size and contour of the electrode. This process is also depending to the welding time where the timer controls by four different steps as shown in Figure 2.3 and Figure 2.4 (Jeffus L., 2011).

1. Squeeze time, or the time between the first application of electrode force and the first application of welding current
2. Weld time or the actual time where the current is flow through the work piece. The right or suitable amount of pressure was applied on the workpiece is very important in order to obtain the quality of the weld.
3. Hold time, the period during which the electrode force is applied and the welding current is shut off.
4. Off period, or the time during which the electrodes are not contacting the work piece.

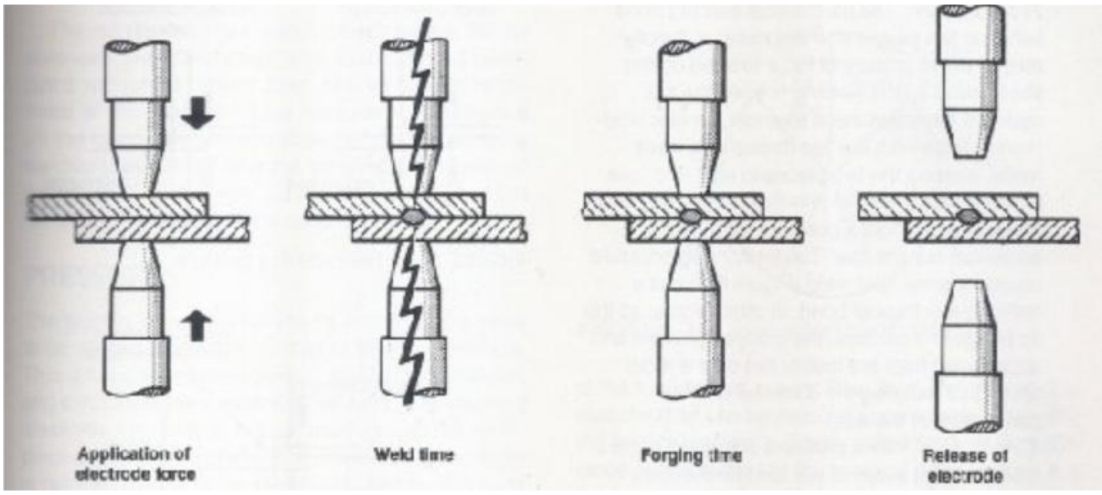


Figure 2.3: Basic period of spot welding.

Source: *Welding principals and Applications* Fourth Edition, pp. 678–681 by Larry Jeffus, 2011.

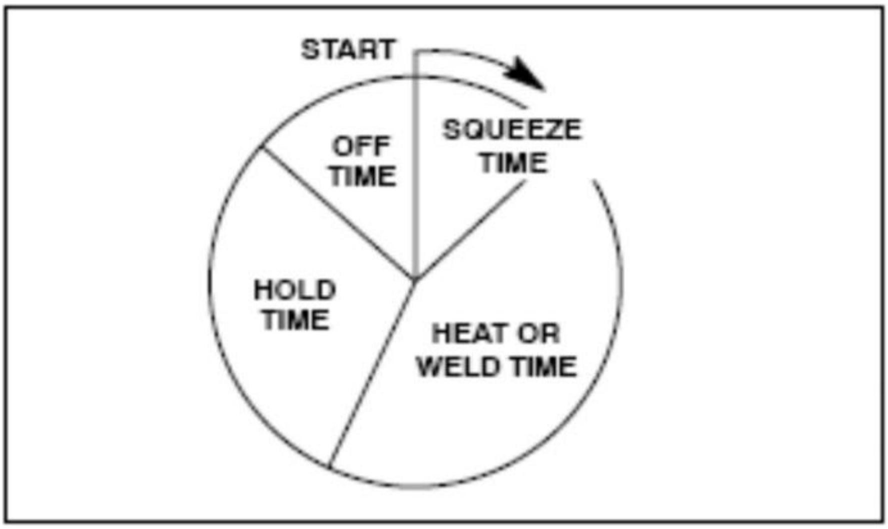


Figure 2.4: Spot weld time cycle

Source: Welding principals and Applications Fourth Edition, pp. 678–681 by Larry Jeffus, 1999.

When electric current is flow through electrode tips to the separate work pieces of metal to be joined, the resistance of the base metal to electrical current flow causes heat and the heat is limited to the area which the tip of the electrode and weld area contacts. While the welding force is maintained, the heat is generating. In the holding stage where the pressure is still maintained, the current is switched off and the nugget is cooled under the pressure (Salem J. *et al.*, 2012).

The major advantages of spot welding are high speed and adaptability for automation in high-volume and/or high-rate production. Despite these advantages, RSW suffers from a major problem of inconsistent quality from weld to weld. This problem results from both the complexity of the basic previous term process next term as well as from numerous sources of variability, noise, and errors. Any or all of these complicate automation, reduce weld quality, demand over-welding like the production of more welds than are structurally needed, if each were perfect, and drive up production costs. (Jou M., 2003)

Resistance spot welding uses the surface resistance of the materials to be joined to generate an intense localized heat under pressure with a short passage of a high current. Use of coated sheet in vehicles for corrosion resistance has presented problems related to the electrode life. The electrode life may get reduced to 50~500 welds before maintenance (tip dressing) as against 3000~6000 welds in case of uncoated plain steels. With introduction of HSLA steels, the need for reliability of weld quality has become much more demanding. Suitable shop floor quality tests are vitally important. (Cho, Y., and Rhee, S. 2003)

Weld timers provide the ability to monitor each spot weld so that its peak current level is within predetermined limits. Dynamic resistance principle measuring the variation of resistance over time during the weld is also used to ensure a higher level of guaranteed quality. A sophisticated dynamic resistance system may incorporate an adaptive control feature that varies the weld settings within certain limits to achieve correct weld quality. The system also includes a weld current stepper function linked to the counting of welds executed. The parameter limits are established for the specific application and programmed for control. With capability of microprocessor based controls, the constant current system could easily be attained for ensuring weld quality

2.2.1 Heat Generation

A modification of Ohm's Law may be made when watts and heat are considered synonymous. When current is passed through a conductor the electrical resistance of the conductor to current flow will cause heat to be generated. The basic formula for heat generation may be stated in Equation 2.1 (Muller, 2012).

$$H = I^2 R \tag{2.1}$$

H = Heat

I^2 = Welding Current Square

R = Resistance

The secondary portion of a resistance spot welding circuit, including the parts to be welded, is actually a series of resistances. The total additive value of this electrical resistance affects the current output of the resistance spot welding machine and the heat generation of the circuit. The key fact is, although current value is the same in all parts of the electrical circuit, the resistance values may vary considerably at different points in the circuit. The heat generated is directly proportional to the resistance at any point in the circuit.

Previously, the formula for heat generation was used. With the addition of the time element, the formula is completed as follows in Equation 2.2:

$$H = I^2RTK \tag{2.2}$$

H = Heat

I^2 = Current Squared

R = Resistance

T = Time

K = Heat Losses

Control of time is important. If the time element is too long, the base metal in the joint may exceed the melting and possibly the boiling point of the material. This could cause faulty welds due to gas porosity. There is also the possibility of expulsion of molten metal from the weld joint, which could decrease the cross section of the joint and weaken the weld. Shorter weld times also decrease the possibility of excessive heat transfer in the base metal.

2.1.1 ADHESIVE BONDING

Adhesive bonding are used for various applications in the modern automotive industry like Figure 2.5. Adhesive types with specific properties are available for miscellaneous processing. The requirements for adhesive bonds have increased due to the extended life of the car. In adhesive processing, industrial health and environmental protection aspects have become more and more important. Therefore, it is more difficult but nevertheless necessary to determine requirements for the adhesives to be used in the future. In addition, the demand for quality standards requiring better quality management is increasing (Cordes E.H., 2003).

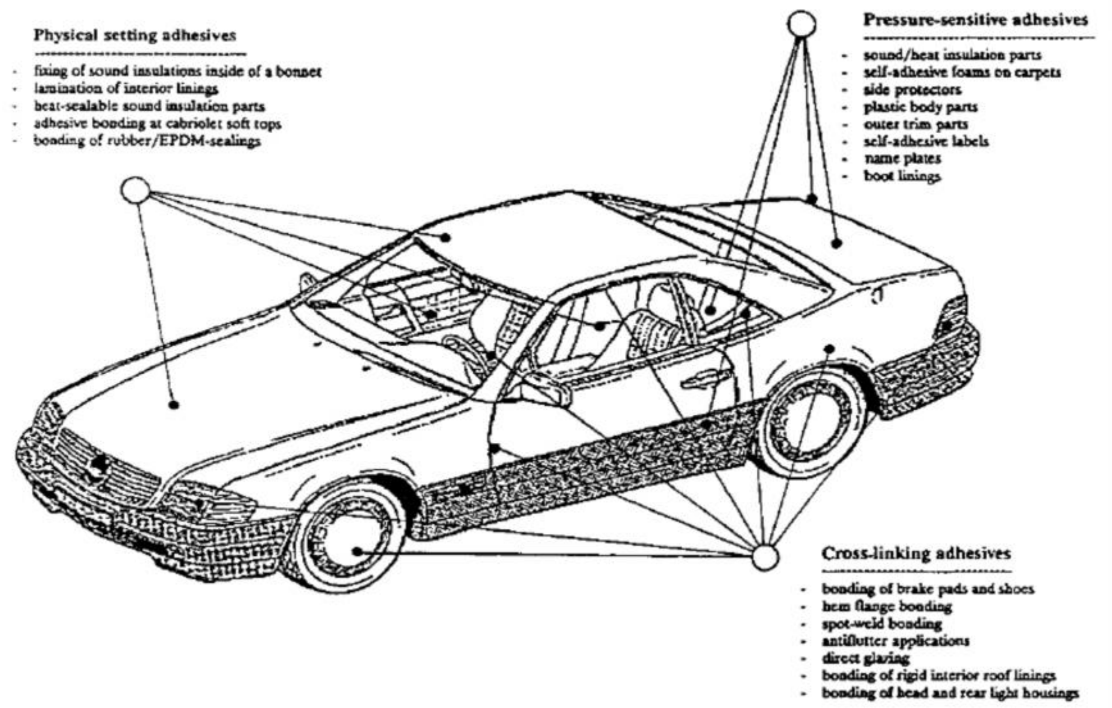


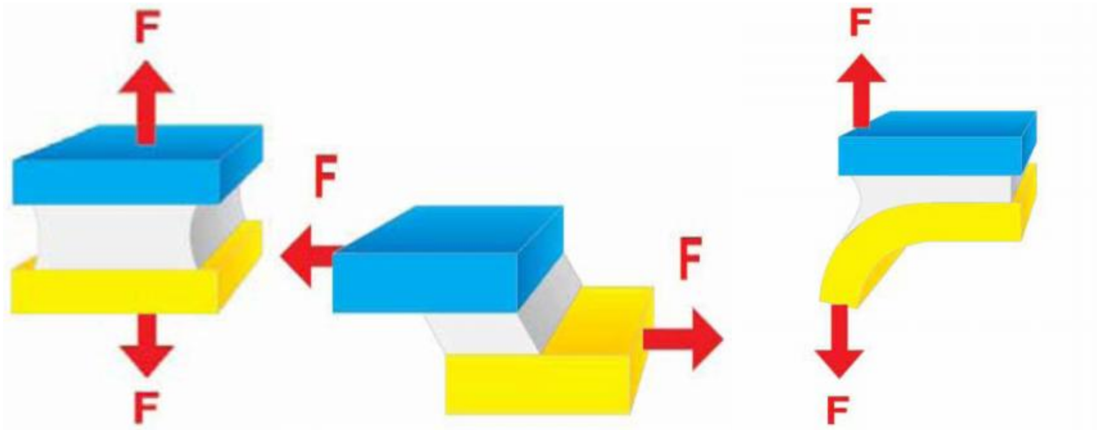
Figure 2.5: Samples of adhesive applications in car production.

Sources: Adhesives in the Automotive Industry by Cordes E. H., 2003.

During car-body design and production is not nowadays just too convectional jointing technologies for stampings. Important role for jointing individual car-body parts plays bonding technology is possible application of adhesives. These days using adhesives do not serve only for sealing function, anti-acoustic or anti-vibration barriers but are also using like structural jointing types which into great extent influence strength and stiffness of car-body and thus its safeness and whole comfort.

For car-body design are up to now using the thinnest sheets which are subsequently jointed mainly by welding. However nowadays there is still increasing tendency to use just bonded joints due to their advantages which represents for jointing of car-body parts. Properly design of bonded joints can in many cases both get out problems with welding and also give the whole construction other profitable properties. Structural bonded joints taken place in automotive industry in many variants both from the design point of view and from the functional loading point of view. Precondition for fine strength and sufficient bonded joints capacity represents mainly suitable joint design.

Bonded joints are known for their very high shearing strength. Tensile strength is much lower and the worse properties are given under peel loading like Figure 2.6 Principles about suitable using of bonded joint are given firstly by character of used adhesive and also by requirement to reduce or eventually minimize tensile and peel loading .If there is not possibility to reduce these factors and is necessary to increase joint safety, bonding is combines with other jointing technologies. In many cases are bonded joints used in combination with spot welding example door trims (Kolnerove M. *et al.*, 2010).



a) b) c)

Figure 2.6: Bonded joint loading: a) Tensile, b) Shear, c) Peel.

Source: Kolnerove M., Doubek P., Solfronk P. and Sobotka J., 2010. Strength of Adhesive Bonding Joints for Classical and Progressive Materials Used For Car-Body Design. *Journal of Materials Processing Technology*, **93** (3): 102

2.3.1 Adhesive Experiment

For evaluation bonded joint quality is another possible criterion to evaluate bonded joint failure type according CSN ISO 10365 like Figure 2.7. Basic failure types are shown with course of peeling test in Figure 2.8 (Kolnerove M. *et al.*, 2010).

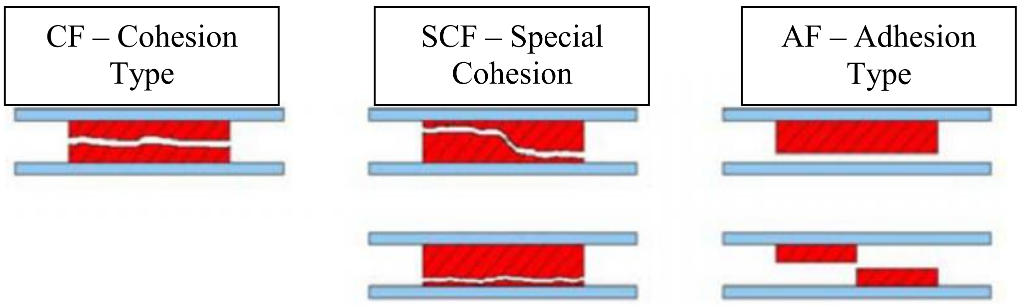


Figure 2.7: Basic failure types of bonded joints.

Source: Strength of Adhesive Bonding Joints for Classical and Progressive Materials Used For Car-Body Design by Kolnerove M. *et al.*, 2010.

Figure 2.8: Peeling Test

Source: Strength of Adhesive Bonding Joints for Classical and Progressive Materials Used for Car-Body Design by Kolnerove M. *et al.*, 2010

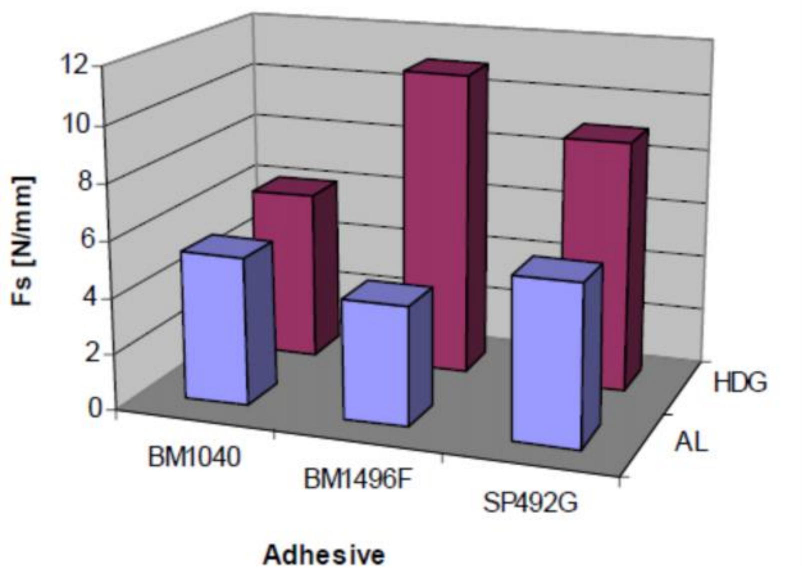


Figure 2.9: Peeling strength test results.

Source: Strength of Adhesive Bonding Joints for ClassicalandProgressive Materials Used For Car-Body Design by Kolnerove M. *et al.*, 2010

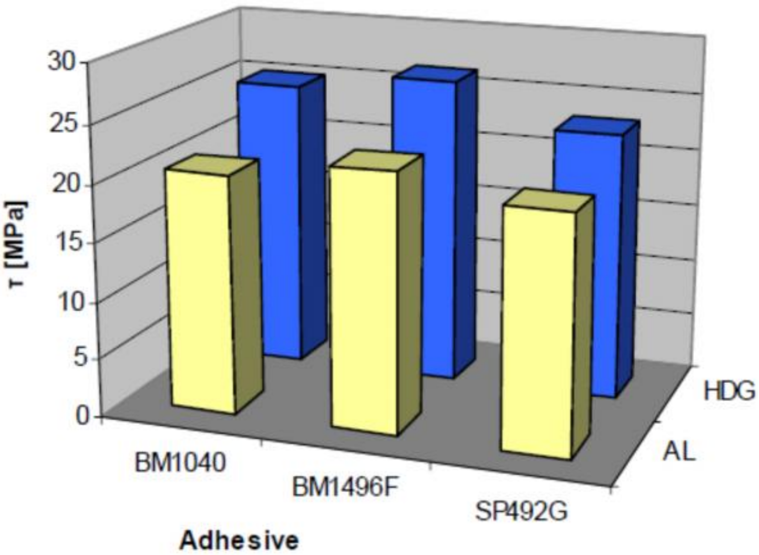


Figure 2.10: Shearing strength test results.

Source: Strength of Adhesive Bonding Joints For Classical And Progressive Materials Used for Car-Body Design byKolnerove M. *et al.*, 2010

Measured results proved presumptions about lower strength of bonded joints from aluminium alloys wit comparison to steel sheets both under shearing loading like Figure 2.9 and also for peel test like Figure 2.10. Such reality is also because due to lower mechanical properties for tested aluminium alloy, however measured values fulfill parameters of bonded joints utility properties. It is really necessary to remind that bonded joints test quality results to a great extent depend on many parameters which influence final values like example. Amount and type of used lubricants, type of used substrate and its surface morphology. With respect to these and many others influences can be stated that for each combination of lubricant, substrate and adhesive have to be tested. Great number of parameters makes testing of bonded joints quality very difficult and there is necessity to carry out another testing and deepening knowledge about individual factors influence and their combination onto bonded joints properties with respect to specific requirements from automotive industry.

2.3.2 Adhesive Applications

In this part, adhesive bonding and sealing in automobile production are subdivided schematically into two ranges of application: mechanical parts production, and the body shop. Depending on the variety of applications, adhesives must satisfy a wide range of requirements. Generally, the bond strength adhesive ability must perform under severe conditions for the life of the car (Cordes E.H, 2003).

Further requirements depend on:

a) Function of the material (e.g. are spot-weld sealants): good corrosion protection, weldability, or chlorine emitted to cause corrosion when over baked, good adhesion on the substrates
b) Processing technique: manual or automatic application, bonding at the assembly line or at a separate working site
c) Specific material characteristics like moisture and or hot-curing adhesive: curing time, stability in storage, flexibility at low temperatures, hydrolytic stability, aging resistance, adhesion properties